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RESEARCH MEMORANDUM

THE EFFECT OF AILERON SPAN AND SPANWISE LOCATION ON THE LOW-SPEED LATERAL CONTROL CHARACTERISTICS OF AN UNTAPERED WING OF ASPECT RATIO 2.09 AND 45° SWEEPBACK

By Rodger L. Naeseth and William M. O'Hare

Langley Aeronautical Laboratory
Langley Air Force Base, Va.

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RESEARCH MEMORANDUM

THE EFFECT OF AILERON SPAN AND SPANWISE LOCATION ON THE LOW-SPEED LATERAL CONTROL CHARACTERISTICS OF AN UNTAPERED WING OF ASPECT RATIO 2.09 AND 45° SWEEPBACK

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SUMMARY

A low-speed lateral-control investigation was made of an untapered complete wing of aspect ratio 2.09 and 45° sweepback with 0.25-chord flap-type ailerons having various spans and spanwise locations. The tests were made at a Reynolds number of 3,100,000.

Aileron effectiveness increased with increase in aileron span. An outboard aileron was appreciably more effective than an inboard aileron of the same span. The variation of rolling-moment coefficient with aileron-deflection angle was linear over the range of angles of attack for an aileron-deflection range of ±20°. Aileron effectiveness could be accurately predicted by the methods of NACA TN 1674 for low angles of attack.

INTRODUCTION

An investigation was made in the Langley 300 MPH 7- by 10-foot tunnel to determine the effect of aileron span and spanwise location on the aileron effectiveness of a 25-percent-chord sealed aileron on an untapered complete wing of aspect ratio 2.09 and 45° sweepback. Lateral-control data are presented for the wing equipped with several spans of outboard and inboard ailerons. The basic aerodynamic characteristics in pitch and the lateral-stability parameters of the wing are also presented herein. The results of the investigation are compared with the aileron-effectiveness values calculated by the method presented in reference 1.

[redacted]

COEFFICIENTS AND SYMBOLS

The data are referred to the stability axes (fig. 1), which are a system of axes with the origin at the center of moments (0.25 mean aerodynamic chord (fig. 2)), and in which the Z-axis is in the plane of symmetry and perpendicular to the relative wind, the X-axis is in the plane of symmetry and perpendicular to the Z-axis, and the Y-axis is perpendicular to the plane of symmetry.

The coefficients and symbols are defined as follows:

C_L	lift coefficient (Lift/qS)
C_D	drag coefficient (Drag/qS where Drag = -X when $\psi = 0^{\circ}$)
C_Y	lateral-force coefficient (Y/qS)
C_m	pitching-moment coefficient ($M/qS\bar{c}$)
C_l	rolling-moment coefficient (L/qSb)
C_n	yawing-moment coefficient (N/qSb)
Y	lateral force, pounds
L	rolling moment about X-axis, foot-pounds
M	pitching moment about Y-axis, foot-pounds
N	yawing moment about Z-axis, foot-pounds
S	wing area, 6.16 square feet
q	free-stream dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$
V	free-stream velocity, feet per second
ρ	mass density of air, slugs per cubic foot
c	local wing chord, feet
$\bar{c}$	wing mean aerodynamic chord, feet $\left(\frac{2}{S}\int_0^{b/2} c^2 dy\right)$
b	wing span, 3.59 feet
b_a	aileron span, feet

y lateral distance from plane of symmetry, measured parallel to Y-axis, feet

y_o lateral distance from plane of symmetry to outboard end of aileron, measured parallel to Y-axis, feet

y_i lateral distance from plane of symmetry to inboard end of aileron, measured parallel to Y-axis, feet

α angle of attack of wing chord plane, degrees

ψ angle of yaw, angle between relative wind and plane of symmetry measured in XY-plane

δ_a aileron deflection relative to wing chord plane, measured in a plane perpendicular to aileron hinge axis and positive when trailing edge is down, degrees

$$C_{L_\alpha} = \frac{\partial C_L}{\partial \alpha}$$

$$C_{l_{\delta_a}} = \frac{\partial C_l}{\partial \delta_a}$$

$$C_{l_\psi} = \frac{\partial C_l}{\partial \psi}$$

$$C_{n_\psi} = \frac{\partial C_n}{\partial \psi}$$

$$C_{Y_\psi} = \frac{\partial C_Y}{\partial \psi}$$

Rolling-moment and yawing-moment coefficients presented represent the aerodynamic moments on a complete wing produced by the deflection of the aileron on only the right semispan of the wing.

CORRECTIONS

Jet-boundary (induced upwash) corrections based on unswept-wing theory (reference 2) were applied to the angle of attack and to the drag data. The data were also corrected for blockage effects by the methods of reference 3, and for model support strut tares.

MODEL AND APPARATUS

The complete-wing model was mounted horizontally on a single strut support in the Langley 300 MPH 7- by 10-foot tunnel in such a manner as to permit measurement of all forces and moments acting on the model. The wing model of 45° sweepback and aspect ratio 2.09 had a taper ratio of 1.0, with neither twist nor dihedral, and had NACA 64A-010 airfoil sections normal to the leading edge (fig. 2). The model was fabricated by means of a sandwich-type construction consisting of a laminated mahogany core enclosed in a covering composed of $\frac{1}{32}$-inch sheet aluminum glued between sheets of $\frac{1}{32}$-inch fir. The right semispan of the wing was equipped with a 0.25-chord aluminum flap divided into four parts by cuts parallel to the plane of symmetry. The various flap segments were set at given deflections by means of hinge clamps on each flap segment. All flap gaps, except the one between the deflected and undeflected flap segments, were sealed for all tests. Outboard ailerons $\left(\text{outboard end at } 0.983\frac{b}{2}\right)$ having spans of $0.983\frac{b}{2}$, $0.741\frac{b}{2}$, $0.500\frac{b}{2}$, and $0.258\frac{b}{2}$ as well as inboard ailerons (inboard end at plane of symmetry) having spans of $0.483\frac{b}{2}$ and $0.242\frac{b}{2}$ were tested.

TESTS

All the tests were performed in the Langley 300 MPH 7- by 10-foot tunnel at an average dynamic pressure of approximately 99 pounds per square foot, which corresponds to a Mach number of 0.26 and a Reynolds number of 3.1×10^{6}, based on the wing mean aerodynamic chord of 1.72 feet.

Data for each test were obtained through an angle-of-attack range from -6° to beyond the wing stall. Lift, drag, and pitching-moment data were obtained for the wing at $\psi = 0^{\circ}$ with $\delta_a = 0^{\circ}$, and lateral-stability derivatives of the wing were obtained from tests at $\psi = \pm 5^{\circ}$. Lateral-control data were obtained with various spans of inboard and outboard ailerons at deflections ranging between $\pm 20^{\circ}$.

DISCUSSION

Wing Aerodynamic Characteristics

The lift, drag, and pitching-moment characteristics of the wing model are presented in figure 3. The value of $C_{L_{\alpha}}$ of 0.042 computed by the method presented in reference 4 agrees very well with the experimental lift-curve slope (measured near $C_L = 0^{\circ}$) of 0.041. The pitching-moment data indicate that the aerodynamic center was about 3 percent mean aerodynamic chord ahead of the $\bar{c}/4$ at low lift coefficients. The wing became stable for lift coefficients above approximately 0.5.

The variation of the wing lateral-stability derivatives with lift coefficient is given in figure 4.

Lateral Control Characteristics

Rolling-moment-coefficient and yawing-moment-coefficient data for various spans of inboard and outboard ailerons are given in figures 5 and 6. The variation of rolling-moment coefficient with aileron deflection at $\alpha = 0^{\circ}$ and 16° for various spans of aileron is shown in figure 7. The control effectiveness parameter $C_{l_{\delta_a}}$ was obtained from cross plots of the data of figures 5 and 6 and is presented in figure 8 as a function of angle of attack. Figure 9 shows the variation of aileron effectiveness with aileron span at $\alpha = 0^{\circ}$ for outboard ailerons.

<u>Rolling-moment characteristics</u>.- The variation of C_l with δ_a was fairly linear over the range of angles of attack for the deflections tested, and aileron effectiveness increased with increase in aileron span (figs. 5 to 7). However, the effectiveness of inboard ailerons was appreciably less than for outboard ailerons of the same span (fig. 7).

The values of $C_{l_{\delta_a}}$ for outboard ailerons decreased slightly with increase in angle of attack up to $\alpha \approx 15^{\circ}$ (fig. 8). Above $\alpha \approx 15^{\circ}$, the effectiveness increased, and then decreased above the wing stall. The effectiveness of the inboard ailerons increased slightly with increase in angle of attack up to $\alpha \approx 9^{\circ}$. Above this angle, the variation of $C_{l_{\delta_a}}$ with α was similar to the variation of the outboard aileron effectiveness. The values of $C_{l_{\delta_a}}$ of outboard ailerons obtained from figure 8 at $\alpha = 0^{\circ}$ are presented in figure 9 plotted against relative location of the inboard end of the aileron. This outboard spanwise effectiveness curve may be used to compute the effectiveness of inboard ailerons because the value of $C_{l_{\delta_a}}$ for an aileron spanning any portion of the wing is the difference between the values of $C_{l_{\delta_a}}$ at the inboard end and $C_{l_{\delta_a}}$ at the outboard end of the aileron span being considered (reference 5). Thus, values of $C_{l_{\delta_a}}$ calculated by this method (from fig. 9) for the two inboard ailerons tested are found to agree with the experimental values shown in figure 8.

Aileron effectiveness $C_{l_{\delta_a}}$ computed for the various aileron spans on the wing of the present investigation by the theoretical and empirical relationships given in reference 1 show excellent agreement with the experimental values of figure 9 - indicating that $C_{l_{\delta_a}}$ can be predicted satisfactorily by this method.

Yawing-moment characteristics.- The sum of the yawing moments produced by equal up and down aileron deflections for each aileron configuration was generally negligible for small angles of attack (figs. 5 and 6). At moderate and large angles of attack, however, the yawing moments were adverse and generally increased with increase in α and δ_a except for the inboard aileron of $\frac{b_a}{b/2} = 0.242$, which produced negligible yawing moments throughout the angle-of-attack and aileron-deflection ranges (fig. 6(b)). At the higher angles of attack, the C_n/C_l ratio amounted to as much as -0.7, indicating that in some instances a sizeable rudder deflection may be required to perform a coordinated roll with an airplane using a wing of this plan form (reference 6).

CONCLUSIONS

A low-speed lateral-control investigation was made of an untapered complete wing of aspect ratio 2.09 and 45° sweepback with 0.25-chord ailerons having various spans and spanwise locations. The tests were made at a Reynolds number of 3,100,000. The results of the investigation indicate the following conclusions:

1. Aileron effectiveness increased with increase in aileron span. An outboard aileron was appreciably more effective than an inboard aileron of the same span.

2. The variation of rolling-moment coefficient with aileron-deflection angle was linear over the range of angles of attack for an aileron-deflection range of ±20°.

3. Aileron effectiveness could be accurately predicted by the method of NACA TN 1674 for low angles of attack.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va.

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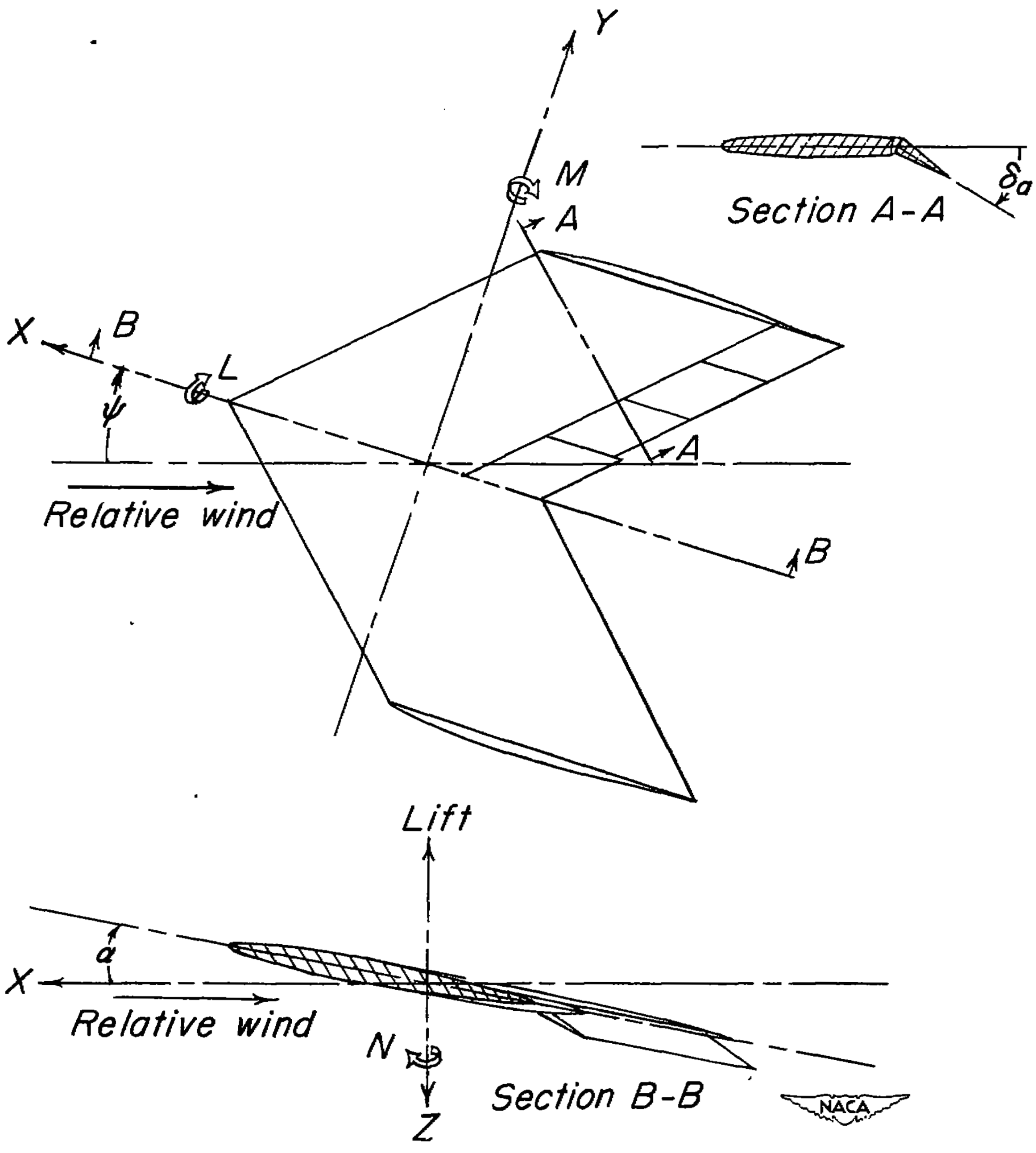


Figure 1.- System of stability axes. Positive values of forces, moments, and angles are indicated by arrows.

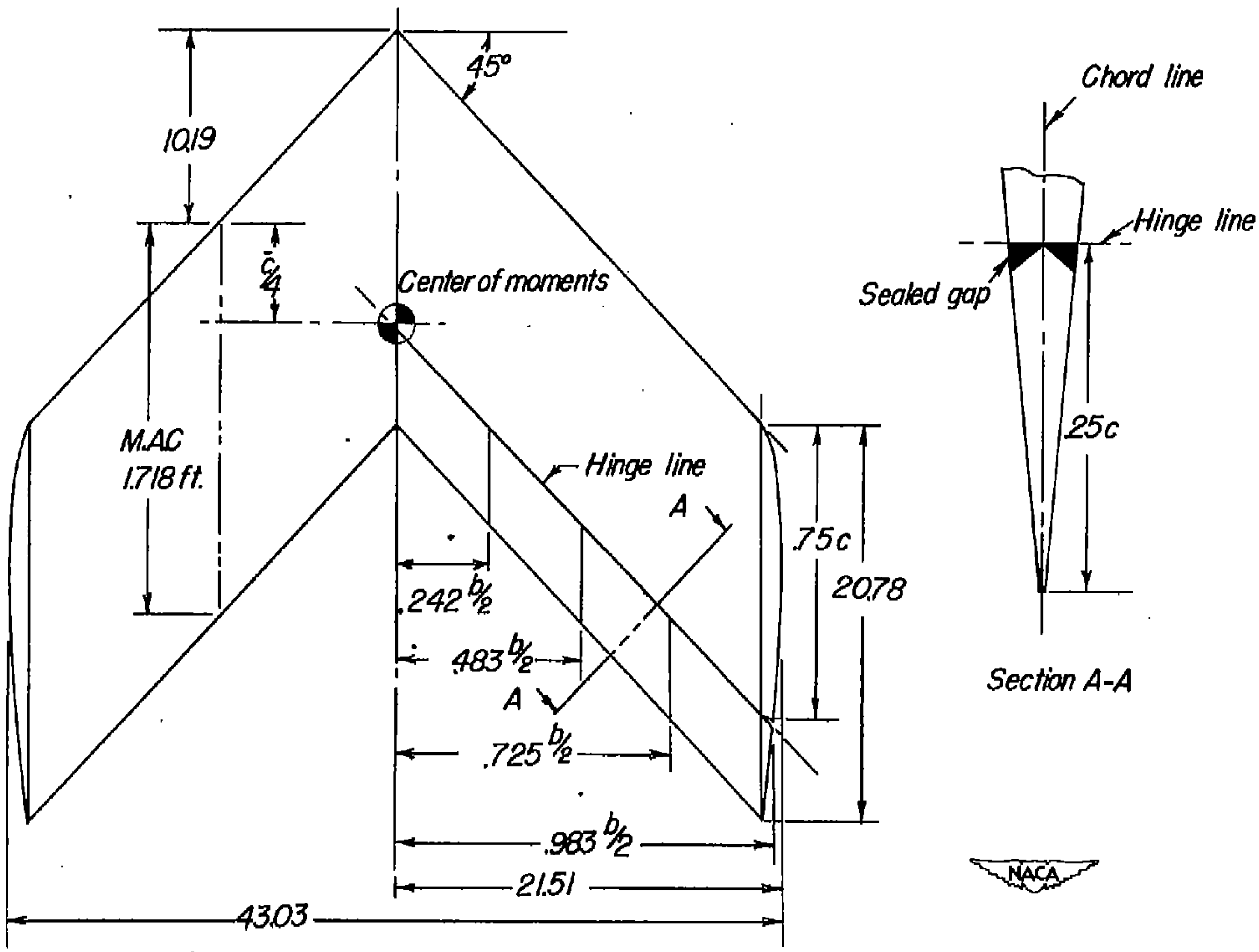


Figure 2.- Sketch of the complete wing model. S = 6.16 sq ft; aspect ratio = 2.09; taper ratio = 1.00. (All dimensions in inches except where noted.)

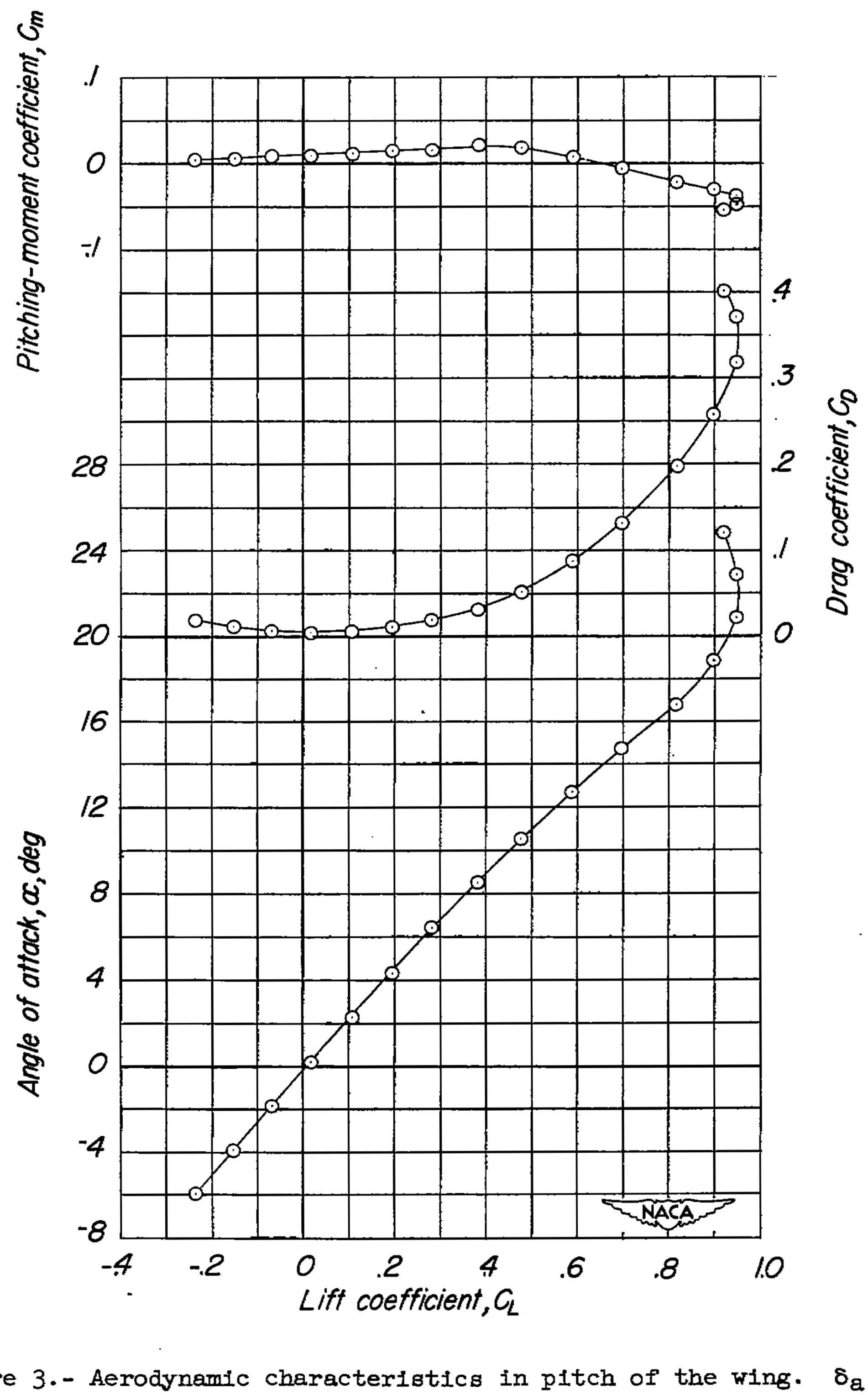


Figure 3.- Aerodynamic characteristics in pitch of the wing. $\delta_a = 0^{\circ}$.

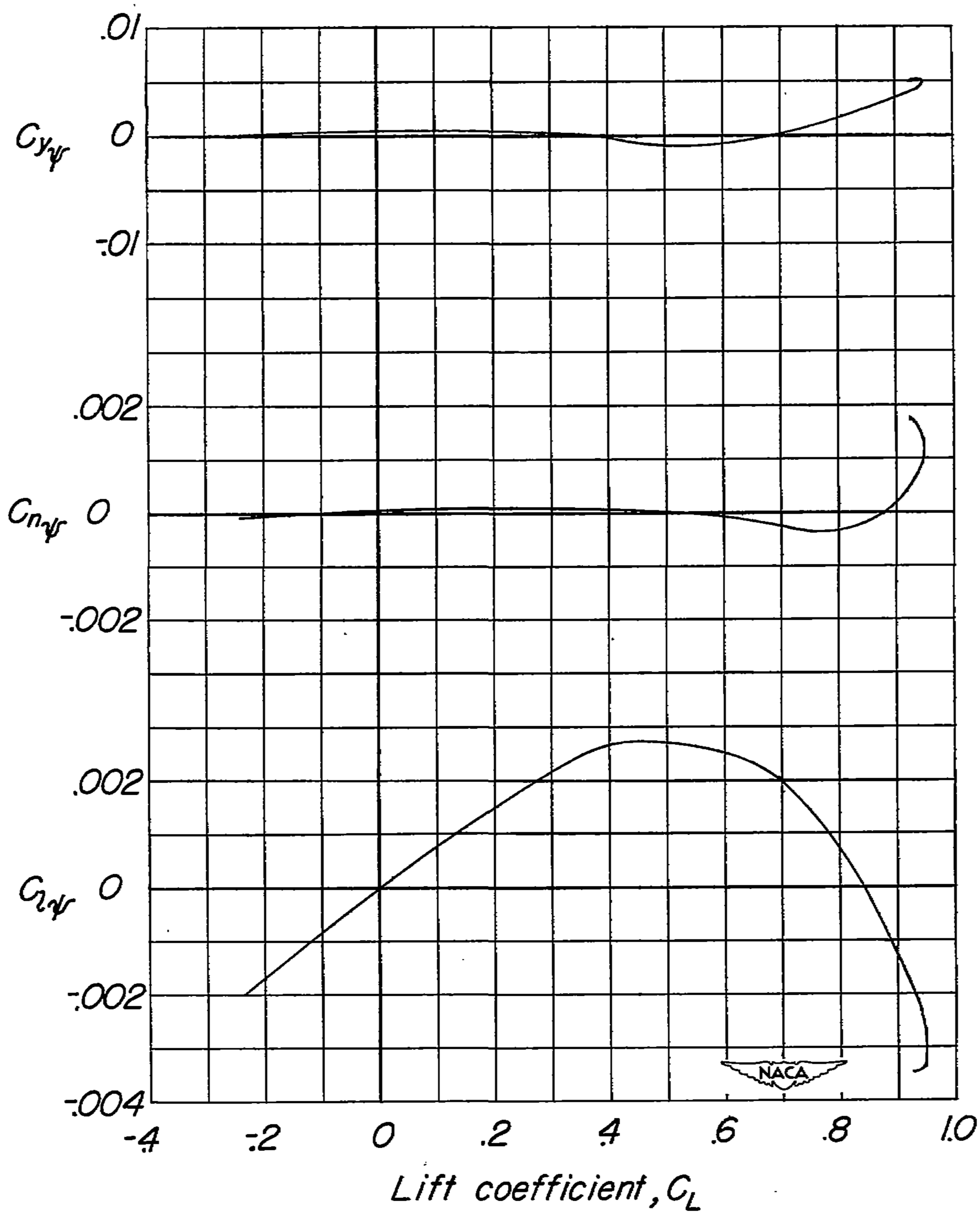
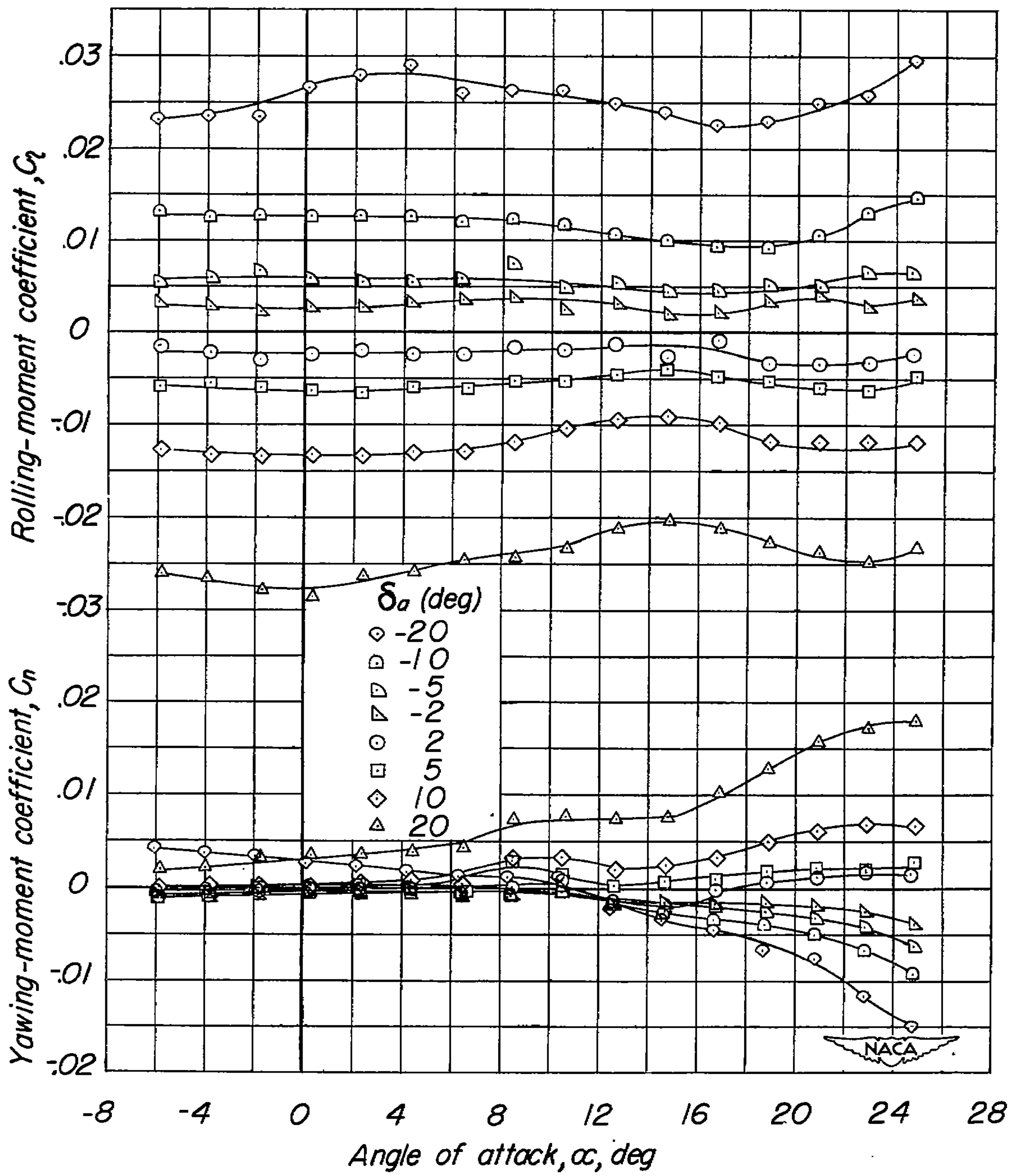
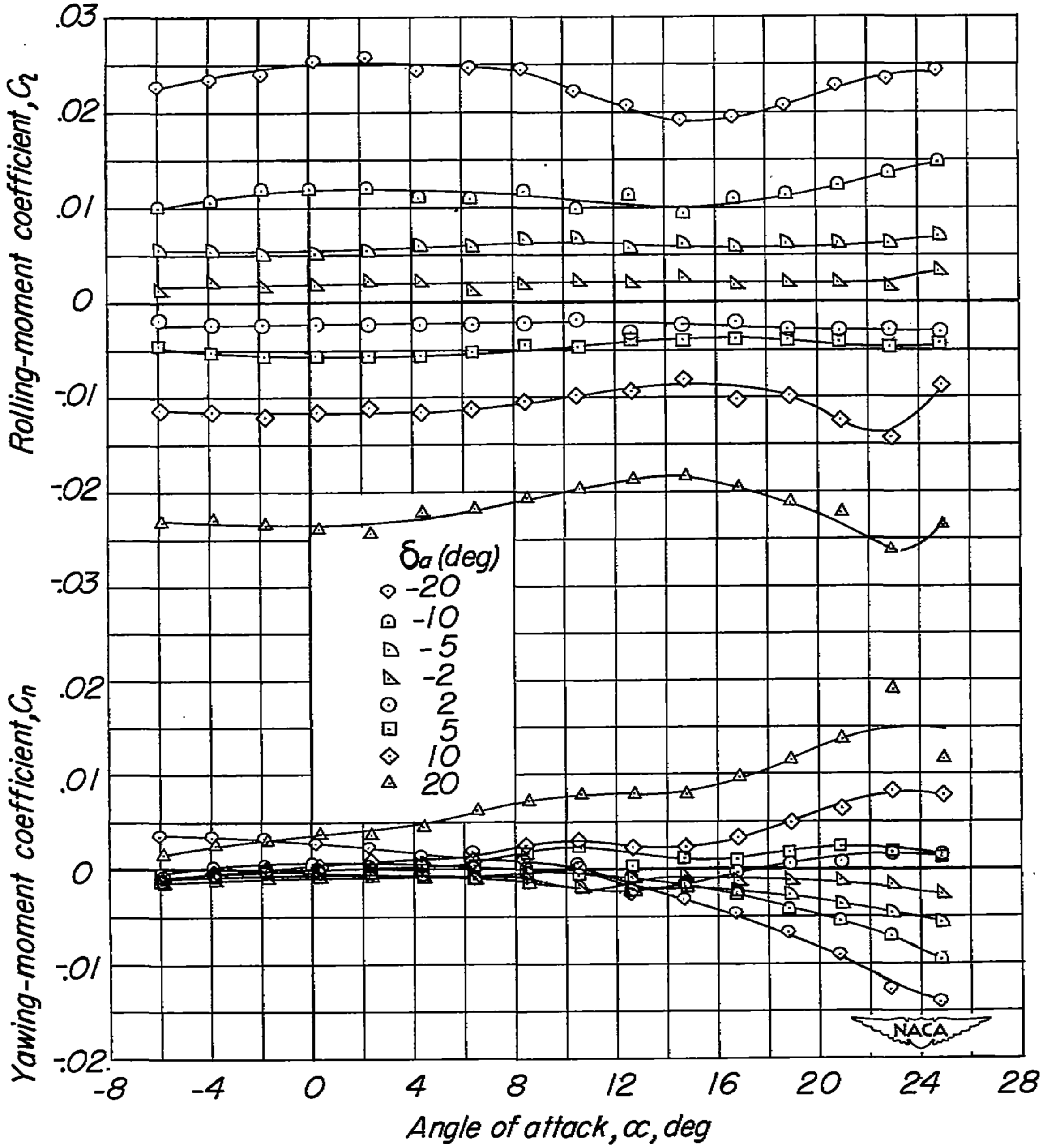


Figure 4.- Variation of the parameters C_{l_ψ}, C_{n_ψ}, and C_{y_ψ} with lift coefficient. $\delta_a = 0^{\circ}$.



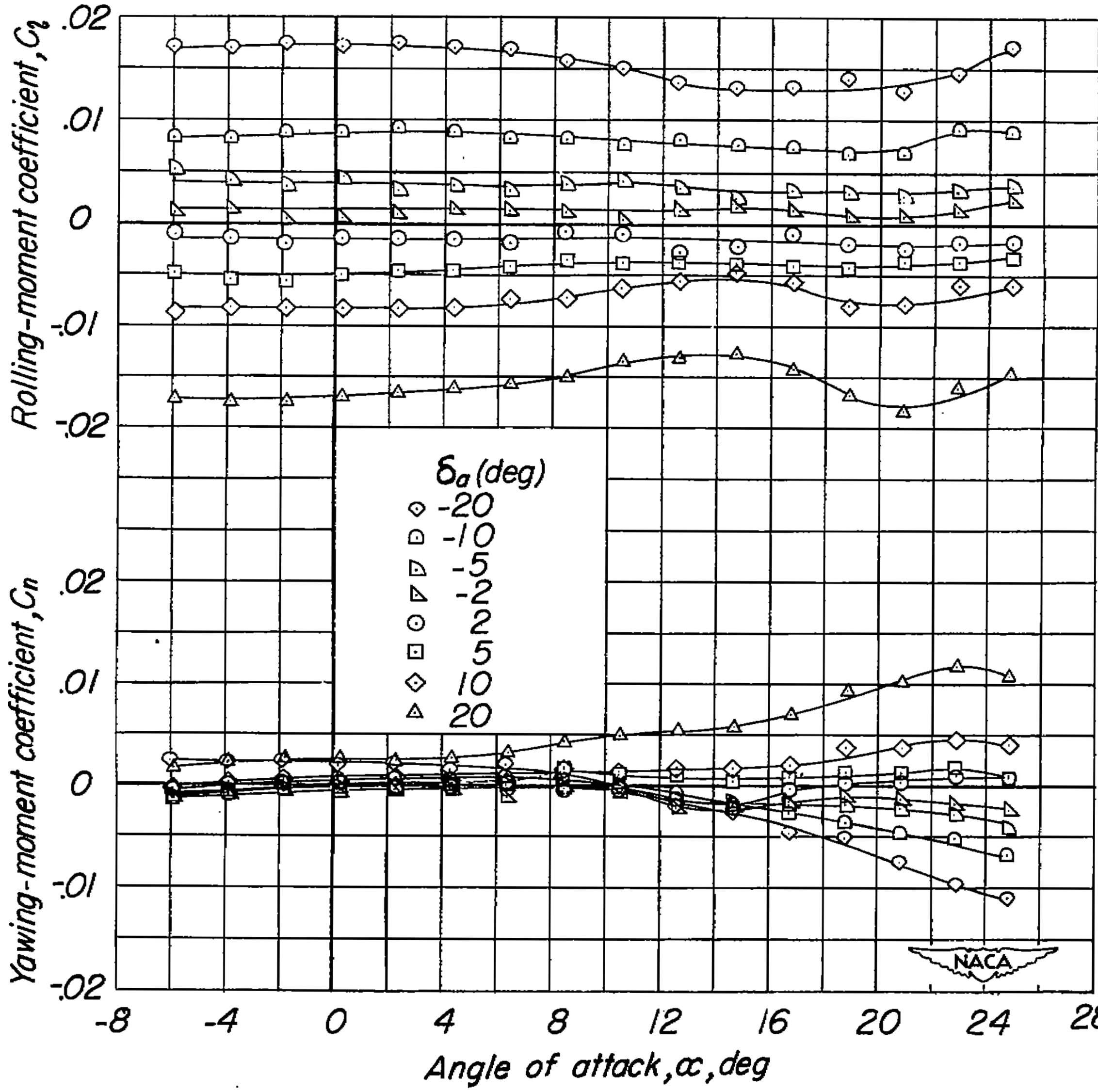
(a) $\frac{b_a}{b/2} = 0.983.$

Figure 5.- Variation of the lateral control characteristics with angle of attack. Outboard ailerons.



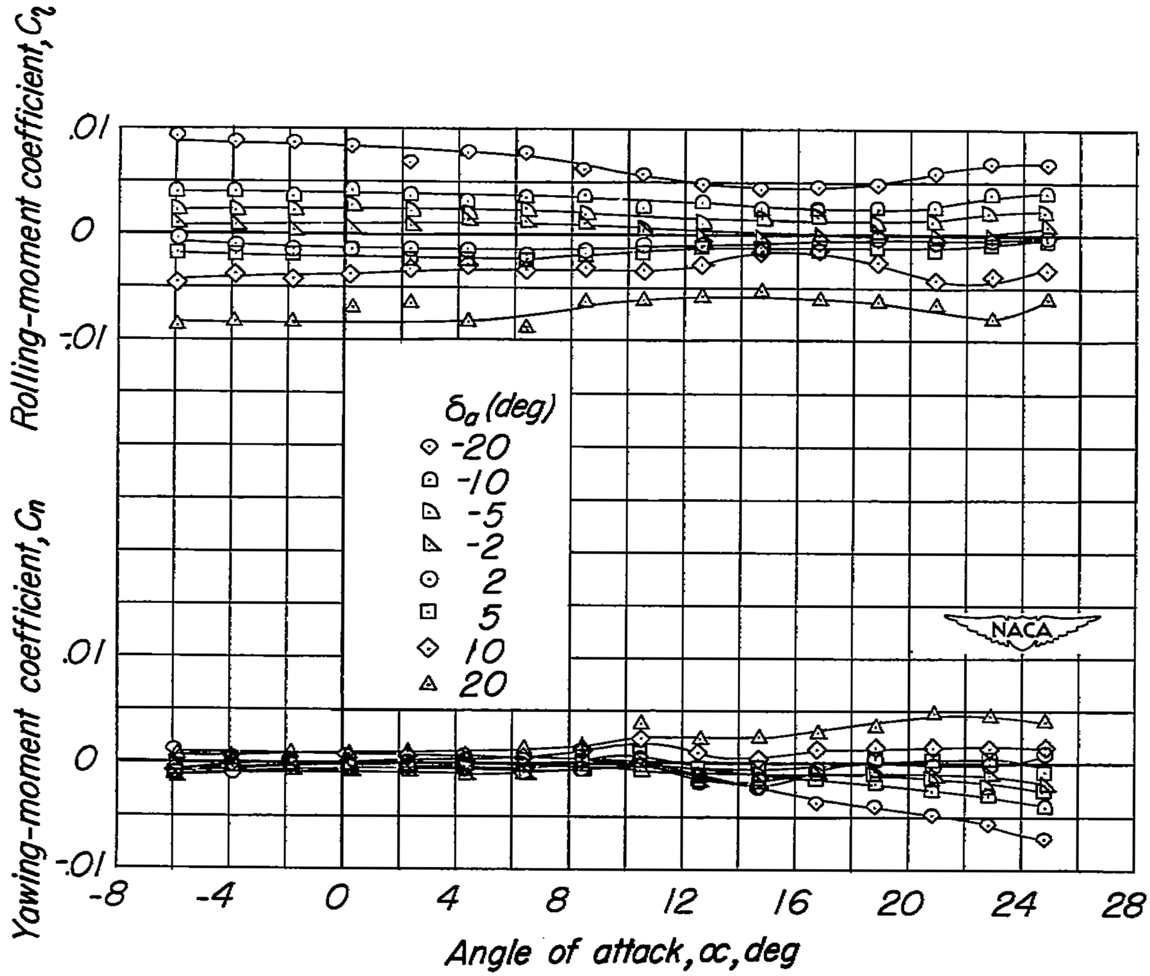
(b) $\frac{b_a}{b/2} = 0.741.$

Figure 5.- Continued.



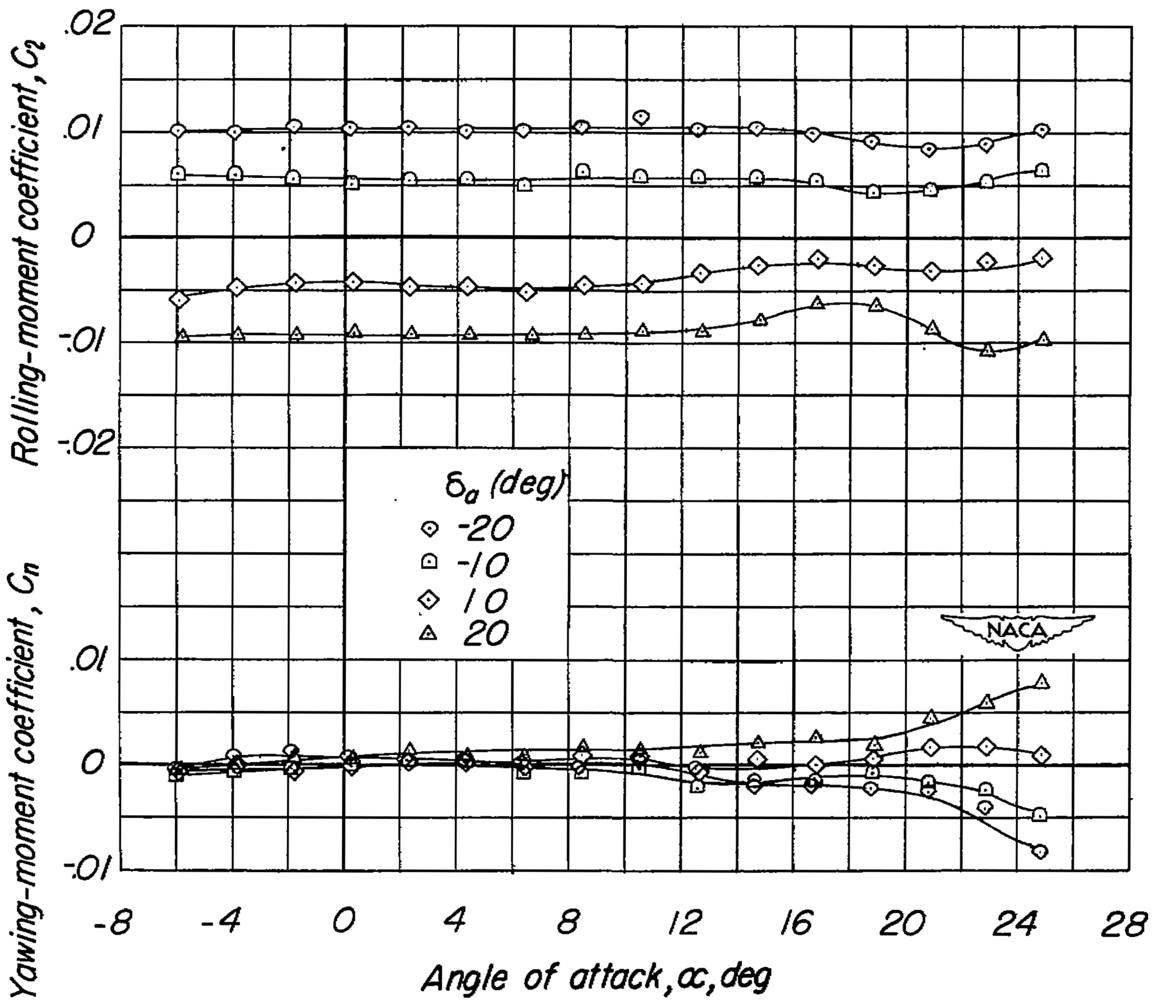
(c) $\frac{b_a}{b/2} = 0.500.$

Figure 5.- Continued.



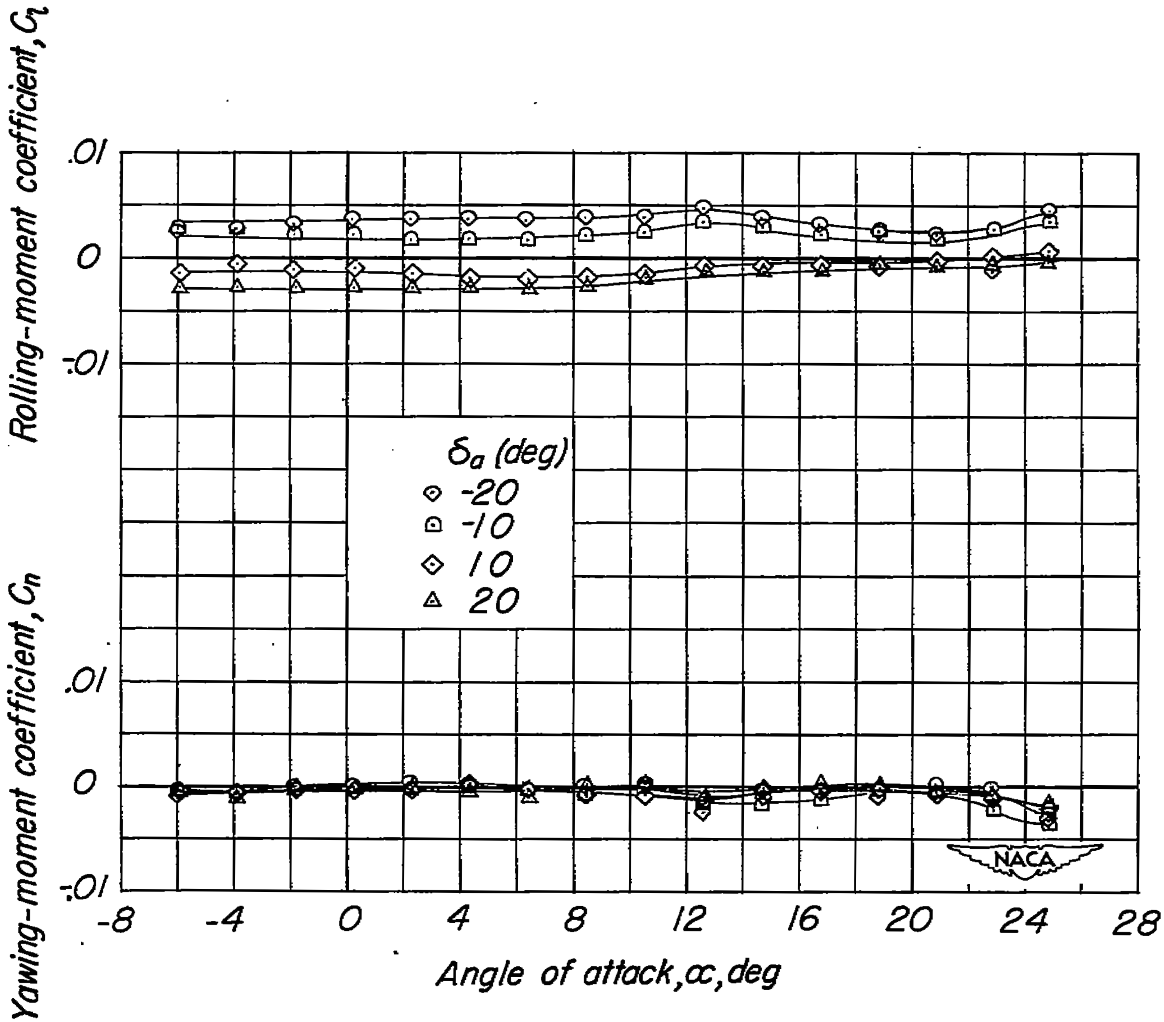
(d) $\frac{b_a}{b/2} = 0.258.$

Figure 5.- Concluded.



(a) $\frac{b_a}{b/2} = 0.483.$

Figure 6.- Variation of the lateral control characteristics with angle of attack. Inboard ailerons.



(b) $\frac{b_a}{b/2} = 0.242.$

Figure 6.- Concluded.

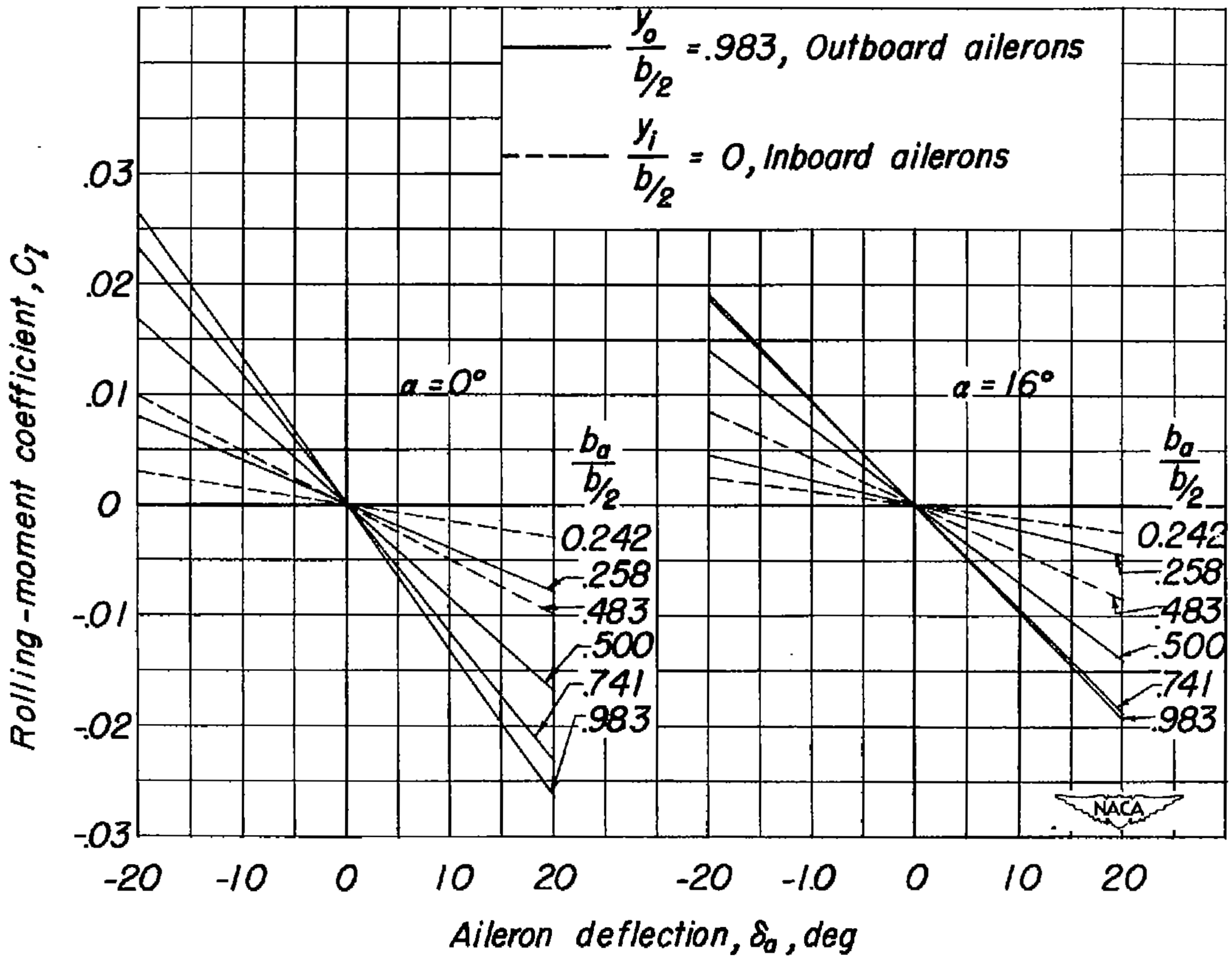


Figure 7.- Variation of rolling-moment coefficient with aileron deflection for various aileron spans.

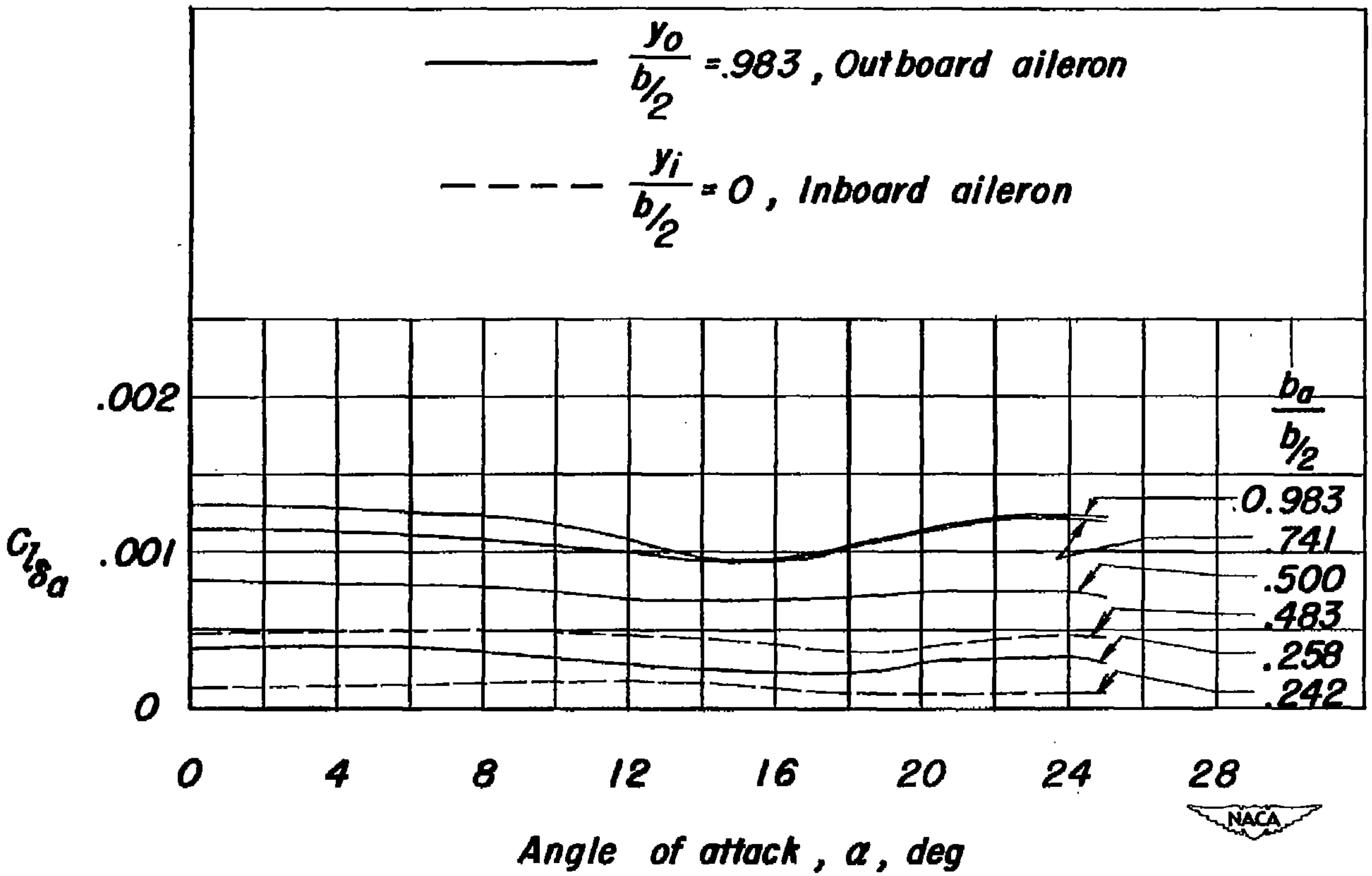


Figure 8.- Variation of aileron effectiveness parameter $C_{l_{\delta_a}}$ with angle of attack for various aileron spans.

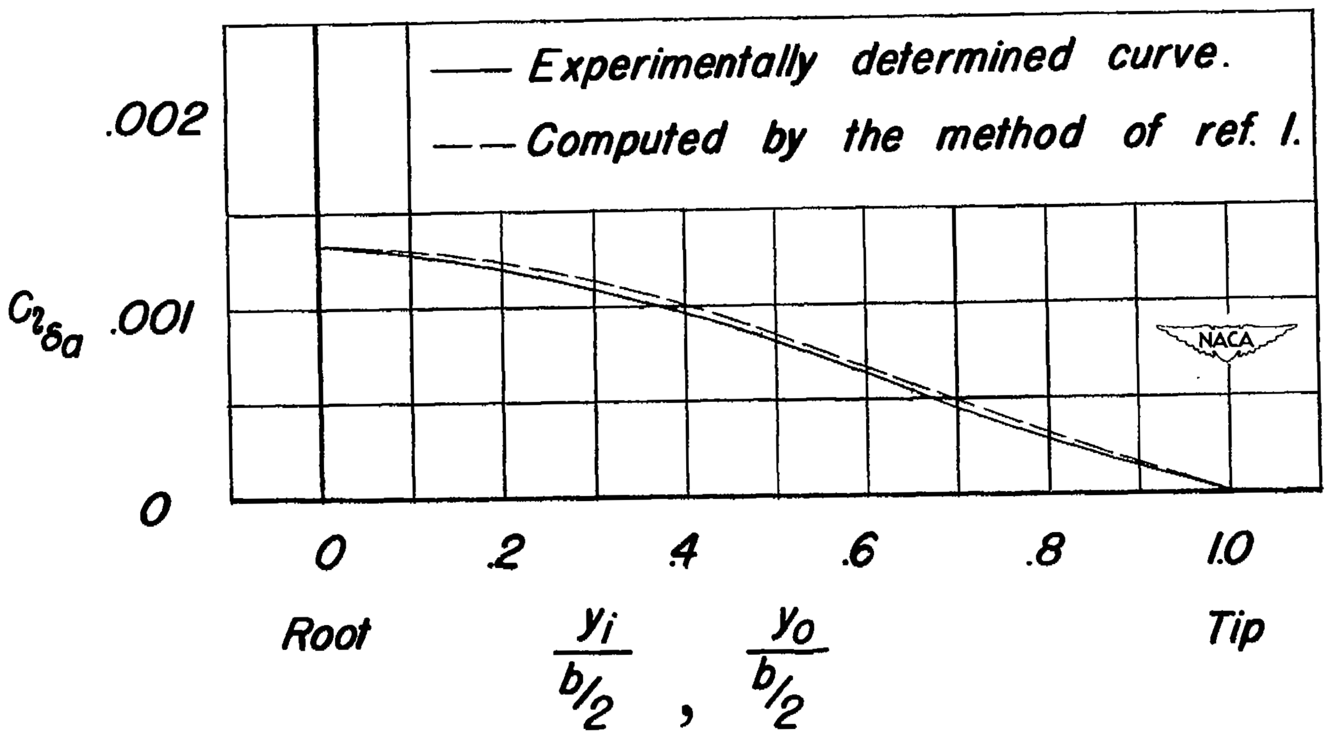


Figure 9.- Variation of aileron effectiveness $C_{l_{\delta_a}}$ with relative position of inboard end of aileron. $\alpha = 0^{\circ}$.